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(54) **Turbocharged Internal Combustion Engine Exhaust Gas Treatment**

(57) A turbocharged internal combustion engine has a chamber containing a catalyst for removal of pollutants from the exhaust gas from the engine by catalytic oxidation of the pollutants.

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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

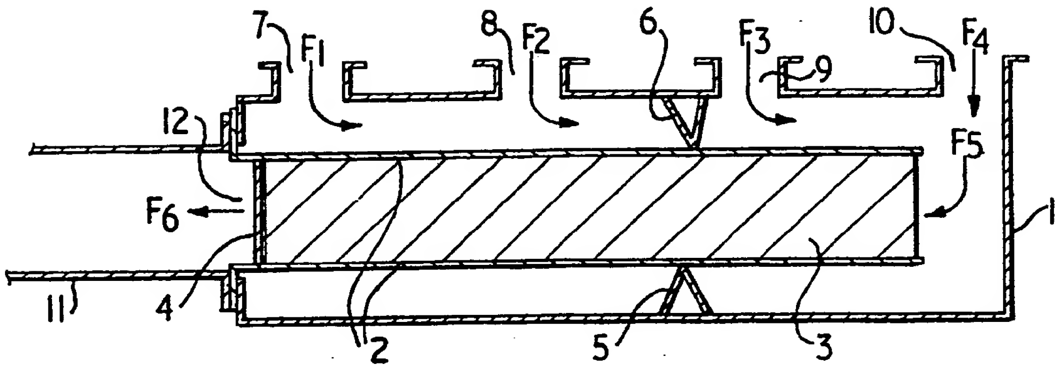
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Fig.1.

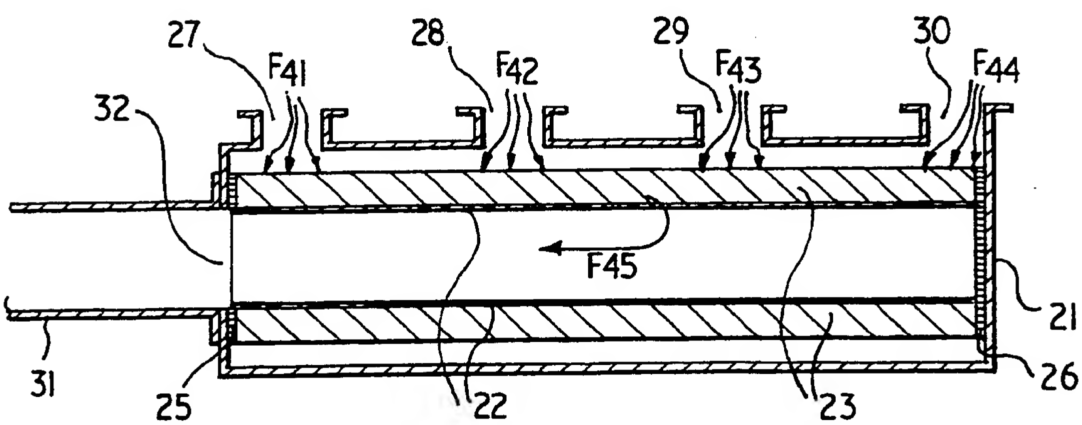
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Fig.2.

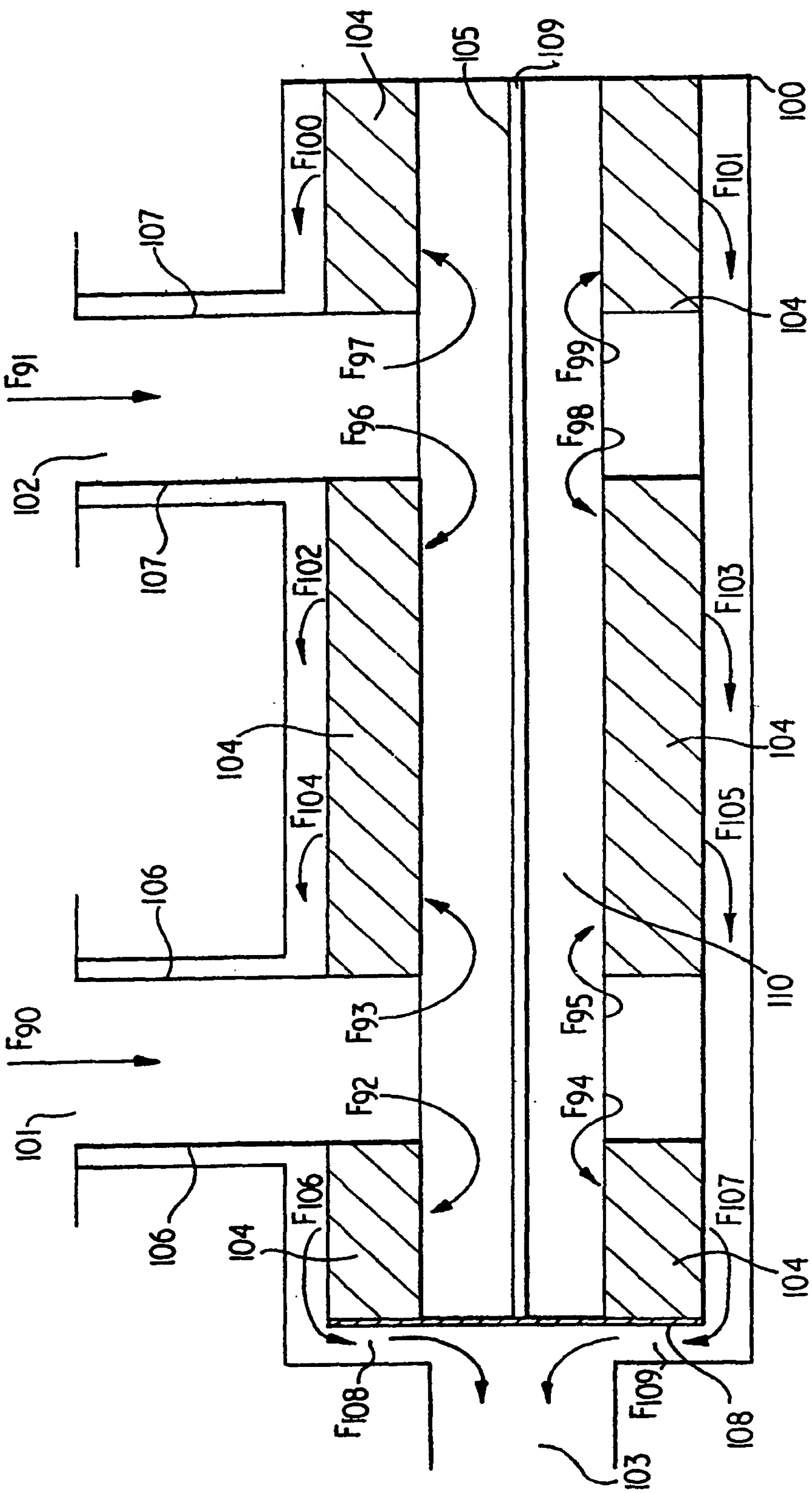
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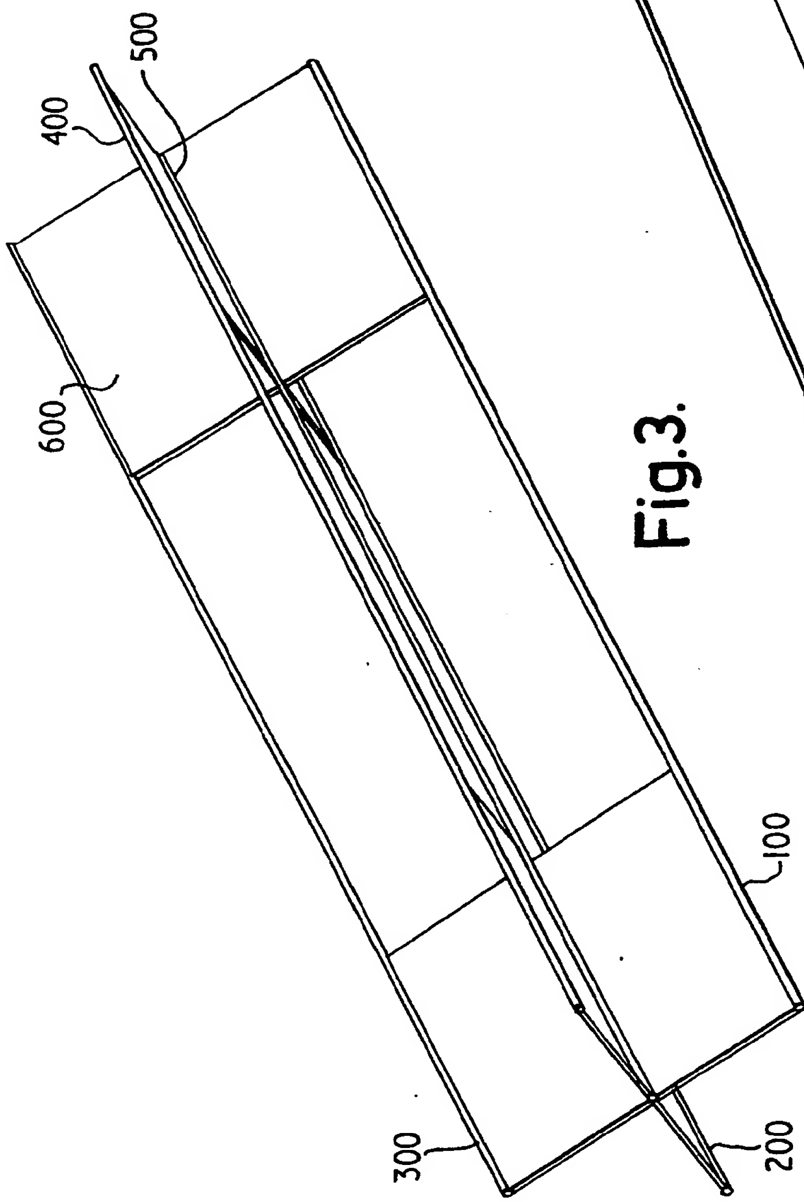
Fig.2A.



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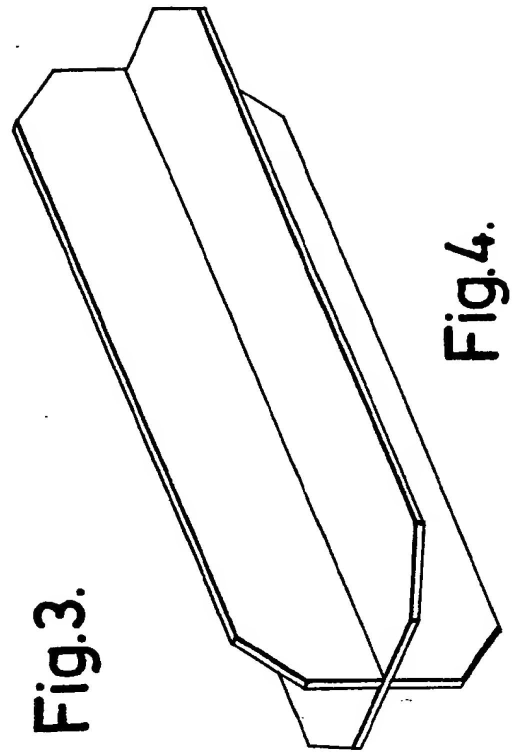

Fig.4.

Fig.5.

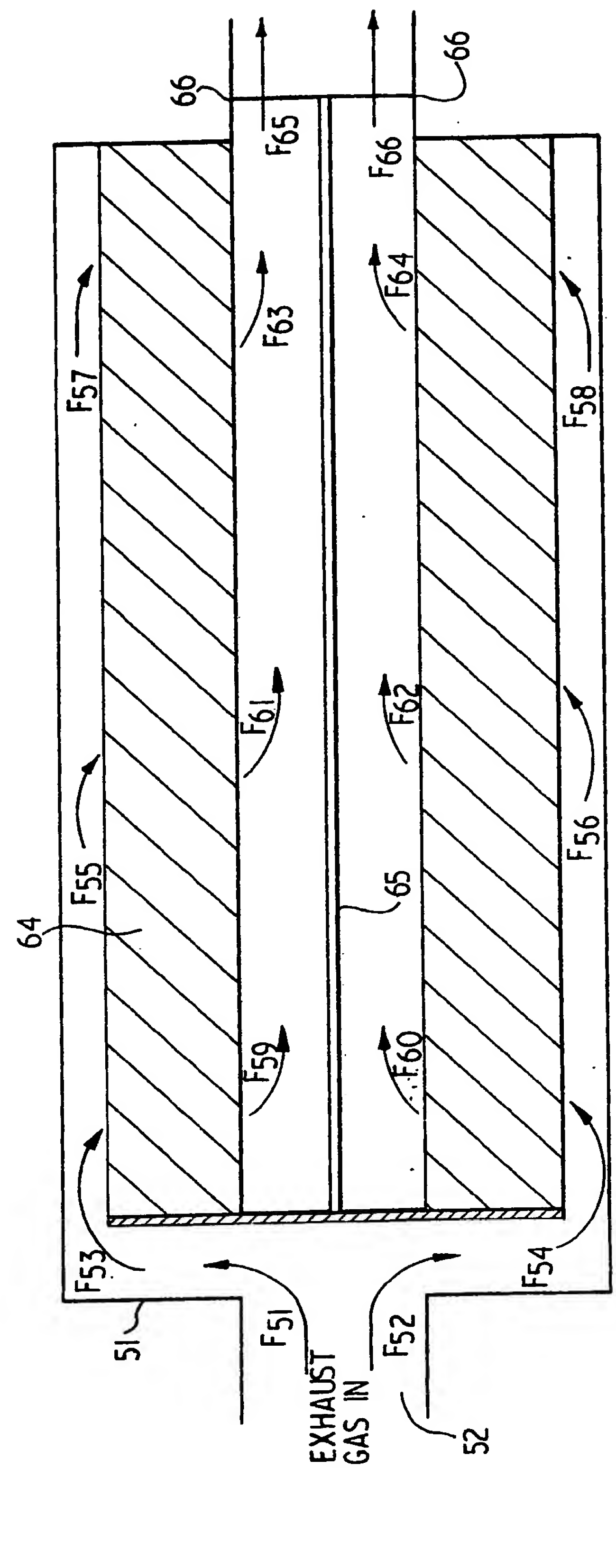
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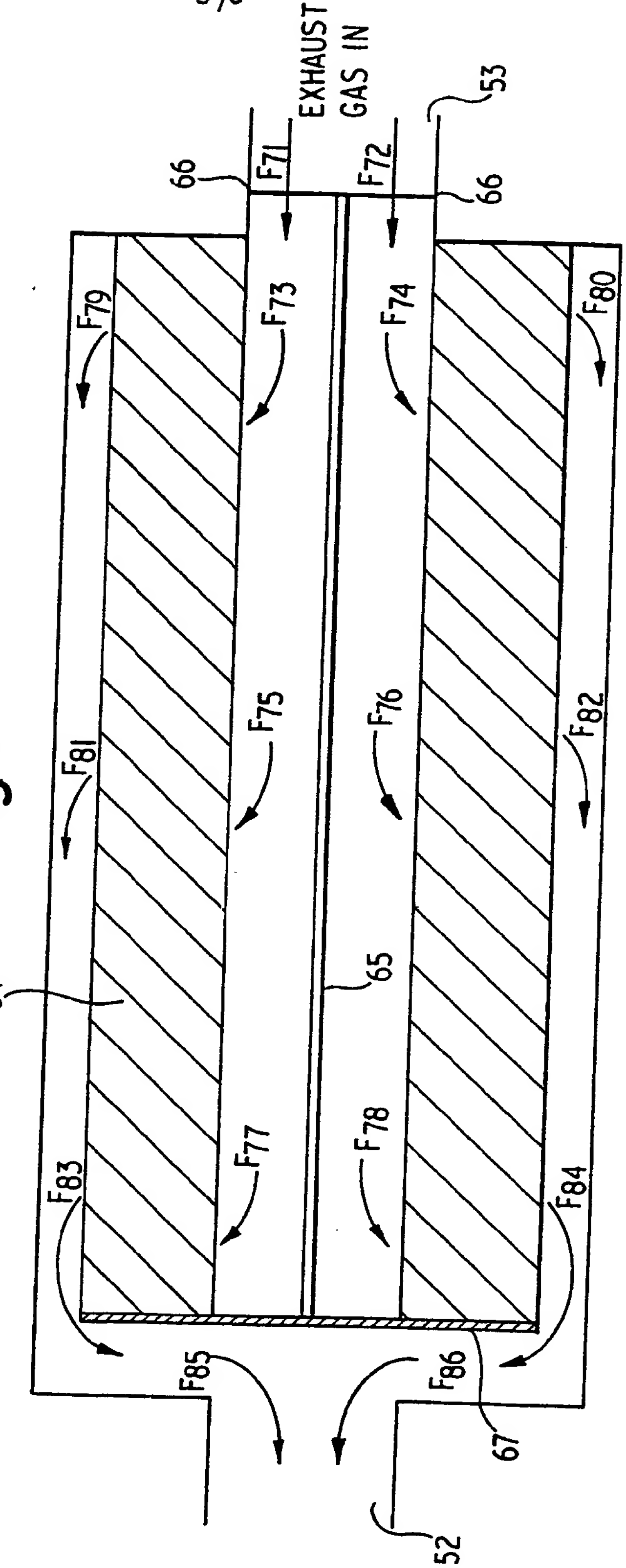
Fig.6.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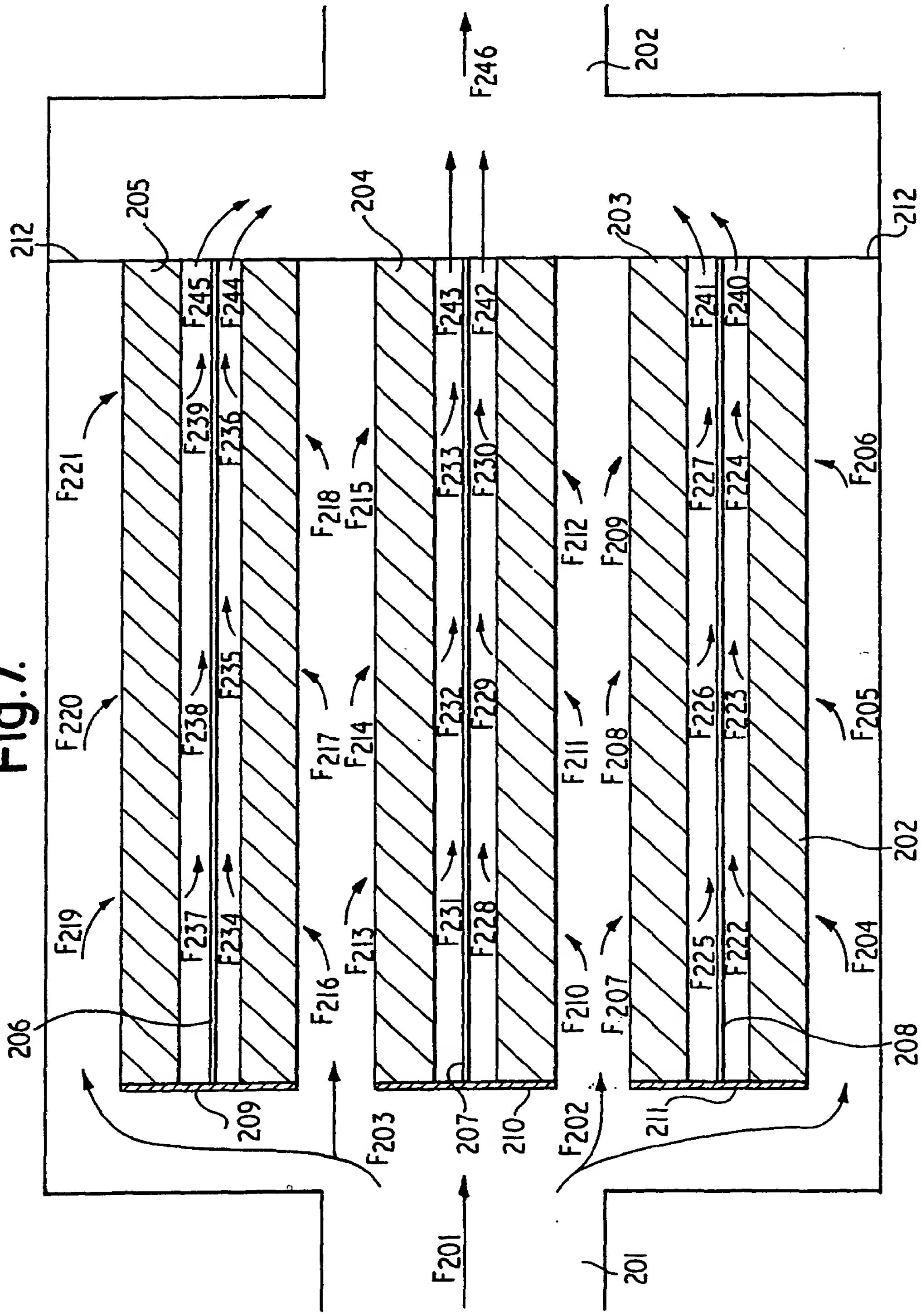

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Fig.7.

SPECIFICATION
Turbocharged I. C. Engines

This invention relates to the reduction of smoke and other noxious components contained in exhaust gases from turbocharged internal combustion engines.

Gases from turbocharged internal combustion engines often contain one or more of the following: finely divided particles of hydrocarbons and carbon and other solids, which emerge as smoke.

The smoke from a diesel engine, for example, is composed of solid particles having a liquid outer covering layer, solid chain aggregates in which spherical particles of between 100—800$\times10^{-10}$m in diameter link up together, liquid sulphates, liquid hydrocarbons and gaseous hydrocarbons. The solid/liquid particles generally comprise carbon particles with adsorbed liquid hydrocarbons and the solid chain aggregates are generally composed of one or both of high molecular weight organic compounds and inorganic sulphates.

When an engine first starts up white smoke is produced which results from the condensation of water vapour on the particles contained in the exhaust gas and a fine mist is formed. Black smoke is produced by diesel engines, formed when the engine has warmed up, and contains a relatively high proportion of carbon particles. In blue smoke there is some carbon but also a relatively high proportion of gaseous organic compounds such as aldehydes. About 90% of these smoke forming particles have a maximum dimension of less than one micron, which is within the respirable particles size, and the maximum dimension of the remaining 10% of the smoke forming particles is less than four microns.

The pollutants include hydrocarbons, carbon monoxide and oxides of nitrogen formed by an internal combustion engine as well as smoke forming particles as described above.

It is an object of the invention to reduce the quantity of pollutants in exhaust gases from turbocharged internal combustion engines.

According to a first aspect of the present invention we propose a turbocharged internal combustion engine having a chamber containing a catalyst for removal of pollutants from the exhaust gas from the engine by catalytic oxidation of the pollutants prior to exit of the exhaust gas from the engine.

Preferably a turbocharged internal combustion engine includes a divided substrate disposed in the path of the exhaust gas flow for inducing turbulence.

According to a second aspect of the present invention, we propose a process for the reduction of pollutants in exhaust gas from turbocharged internal combustion engines comprising passing the exhaust gas from the cylinders of the engine through a chamber containing a catalyst such that the pollutants present in the exhaust gas come into contact with the catalyst and at least part of the pollutants undergoes catalytic oxidation.

The catalytic oxidation of carbon particles takes place at about 400°C whereas the normal temperature of combustion of these particles is 700—800°C. For hydrocarbon particles catalytic oxidation takes place at about 200°C. Since the presence of a catalyst enables oxidation of the smoke forming particles in a gas to take place at a lower temperature than the normal temperature at which combustion takes place, little or no heating of the exhaust gas from an internal combustion engine is required, when it is desired to effect the catalytic oxidation of any smoke forming particles in a gas. A diesel engine, for instance, runs at about 400°C when operating at medium to full power so that no preheating of the exhaust gas issuing from a diesel engine would be required before passing the exhaust gas over a catalyst.

A metallic wire substrate is disposed so as to provide maximum contact of the catalytic metal with the said exhaust gases. Preferably the wire is in a flattened form, usually obtained by rolling pri r to the deposition of washcoat and catalytic metal. In the operation of the engine in which an excess of air or oxygen is present in the combustion chamber such contacts ensures that a substantial proportion of the pollutants as above described undergo catalytic oxidation.

Several embodiments of the present invention will now be described by way of example with reference to the accompanying drawings, in which:—

Figure 1 shows a first embodiment in which a catalyst chamber is adjacent the exhaust ports of the cylinder of an engine;

Figure 2 is a second embodiment in which an alternative catalyst chamber is shown;

Figure 2a is a third embodiment in which yet another alt rnative catalyst chamber is shown;

Figure 3 shows an alternative means of ensuring that the catalyst support does not collapse inwards;

Figure 4 shows an alternative means to that shown in Figure 3;

Figure 5 illustrates a fourth embodiment for positioning adjacent the turbocharger;

Figure 6 is another embodiment for positioning adjacent the turbocharger; and

Figure 7 illustrates the plurality of catalyst chambers.

In a first embodiment of the present invention as shown in Figure 1, a catalyst is contained in a reaction tube which is positioned substantially centrally in an exhaust chamber. An outer wall 1 of the exhaust chamber has openings 7, 8, 9 and 10 which are adjacent and contiguous with the exhaust

ports of the cylinders of an internal combustion engine and one exit 12, adjacent the exhaust pipe 11. Th reaction tube 2 which is supported in the chamber by struts 5 and 6 contains a supported catalyst 3. The reaction tube is positioned so that the exhaust gas from the cylinders on entering the exhaust chamber has to pass through the reaction tube and come into close and continuous contact with the catalyst before leaving the exhaust chamber and then entering the exhaust pipe. The exhaust gas flow through the exhaust chamber is generally indicated by the labelled arrows F_1, F_2, F_3, F_4, F_5 and F_6. Combusted gas flows in from the cylinder ports through the openings 7, 8, 9 and 10 and flows along the reaction tube 2 and out into the exhaust pipe 11. A retaining bar 4 is located across the exit of the reaction tube to ensure that the catalyst is retained in position.

The catalyst is in the form of a catalytic layer on a catalyst support which is preferably of knitted wire mesh; this support may be fabricated as a single monolith or it may be made up of annular sections. A layer of washcoat and the catalytic layer may be applied to each section before or after the sections have been linked together; alternatively the support (in sections or linked together) may have the washcoat and catalytic layer applied after it has been placed in the reaction tube.

A second embodiment is described with reference to Figure 2. The outer wall 21 of the catalyst chamber has openings 27, 28, 29 and 30 adjacent and contiguous with the exhaust ports of the engine cylinders and one exit 32 adjacent the exhaust pipe 31. The catalyst 23, comprising a support, a washcoat layer and a catalytic metal, is disposed so that the exhaust gas on entering the catalyst chamber is compelled to pass through the interstices of the said catalyst before leaving the chamber and subsequently entering the exhaust pipe. The gas flows in from the exhaust ports as shown by F_{41}, F_{42}, F_{43} and F_{44} and then through the catalyst and out into the exit tube 22 as shown by F_{45}.

In this embodiment the support for the catalyst is preferably of knitted wire which may be made up into sections or as one unit but if it is in sections, e.g. in a doughnut configuration, these are usually linked together before the support is placed in the chamber. One end of the support is closed off by joining, e.g. by welding, a disc 26 to it and an annular disc 25 at the other end holds the support in position. The supported catalyst is disposed in the catalyst chamber by attaching the ends covered by the discs 25 and 26 to the outer walls of the chamber. To ensure that the support does not collapse inwards, a cylindrical perforate exit tube 22 positioned in the catalyt chamber allows gas through and to the exhaust pipe 31. The tube 22 may be e.g. wire mesh or a perforate metal tube having holes or slots.

An alternative embodiment as shown in Fig. 3, has in place of the perforate exit tube in the catalyst chamber a series of five rigid bars 100, 200, 300, 400, 500 extending along the length of the chamber. These bars are fixed spatially with respect to one another holding the supported catalyst rigidly in place within the chamber by the use of spacing plates 600. Pairs of the spacing plates 600 each connect three of the five bars and are usually at right angles to each other thus being disposed along a diameter of the central cylindrical exit tube. Two or more pairs of spacing plates may be used and they are usually positioned at regular intervals along the length of the chamber. Alternatively, the spacing plates may be used without bars where they are to be continuous along the length of the chamber as shown in Figure 4. The bars and spacing plates need to be constructed of a material resistant to oxidation up to 800°C.

Another embodiment is described with reference to Figure 2A in which for convenience only two exhaust ports are shown. The outer wall 100 of the catalyst chamber has openings 101 and 102 adjacent and continuous with the exhaust ports of the cylinders and one exit 103 adjacent the exhaust pipe. The catalyst 104 comprising a support, a washcoat layer and a catalytic metal is disposed so that the exhaust gas has to pass through the catalyst before leaving the chamber. The catalyst is disposed in the chamber using spacing plates 105. One end of the spacing plates 109 is fixed to the chamber wall 100, and a disc or metal plate 108 is attached to the other end of the spacing plates to ensure that no exhaust gas is able to leave the chamber without passing through the catalyst. The exhaust gas flows into the chamber through the openings 101 and 102 and down through sleeves 106 and 107 into the inner space 110 provided by the spacing plates 105. The exhaust gas flows through the catalyst outwards and then through the exit 103. The flow of the exhaust gas is indicated by arrows labelled F_{90}—F_{109}.

The support for the catalyst is preferably knitted wire which may be made up into four sections or three units. If the support is in sections e.g. of doughnut configurations, these are normally linked together before the support is placed in the chamber. Another embodiment will be described with reference to Figures 5 and 6. A catalyst chamber with an outer wall 51 has openings 52 and 53. A catalyst 64 comprises a support, a washcoat layer and a catalytic metal and is so disposed that the exhaust gas has to pass thr ugh the catalyt before leaving the chamber. The support is pref rably knitted wire which may be in one unit r a number of sections, e.g. having a doughnut configuration, which are normally linked together before the support is placed in the chamber. The catalyst is disposed in the chamber using spacing plates 65. One end of the spacing plates 66 is attached to the chamber wall and at the other end a disc or metal plate is attached to prevent exhaust gas leaving the chamber without passing through the catalyst.

The catalyst chamber is suitable for positioning between the turbocharger and the exhaust pipe. The opening 52 may be adjacent and contiguous with the outlet of the turbocharger and the opening

53 will be the exit adjacent to the exhaust pipe. The flow of the exhaust gas through the catalyst chamber is from the outside inwards as shown by arrows labelled F_{51}—F_{66} in Figure 5.

The catalyst chamber may also be positioned with the opening 53 adjacent and continuous with the outlet of the turbocharger and the opening 52 adjacent and continuous with the exhaust pipe s that the flow of the exhaust gas is from the inside outwards as shown by arrows labelled F_{71}—F_{86} in Figure 6.

When the catalyst chamber is fitted to a large capacity engine more than one catalyst may be present in the chamber as shown in Figure 7. The supported catalysts 203, 204, 205 as described above are positioned in the chamber using spacing plates 206, 207, 208. One end of the spacing plates 212 is attached to the chamber wall and metal discs or plates 209, 210, 211 are attached to the other end. The flow of the exhaust gas through the chamber is shown by arrows labelled F_{201}—F_{246} in Figure 7.

Example 1

A (2000 capacity) multicylinder engines of a commercially available diesel engine powered automobile fitted with a turbocharger was modified to demonstrate the results obtained in the operation of the present invention. A catalyst chamber as outlined in the last embodiment described above with reference to Figures 5 and 6 was fitted between the outlet of the turbocharger and the exhaust pipe.

The results for catalyst chamber A were taken from measurements with the exhaust gas flowing from the central passageway of the chamber outwards through the catalyst as shown in Figure 6 and for catalyst chamber B the measurements were taken with the exhaust gas flowing through the catalyst towards the central passageway as shown in Figure 5.

The substrate for the catalyst was fabricated from knitted 310 stainless steel wire of diameter 0.254 mm which had been flattened. A layer of washcoat containing alumina, barium oxide and ceria was applied at a loading of 0.34 gg^{-1} wire. The washcoated support was impregnated with 5.7% Rh, 94.5% Pt at a loading of 918 g cm^{-3}. The volume of substrate used was 2114.6 cm^{-3}. The measurements were taken after the car had been driven 250 miles.

The results were obtained by driving the automobile through the LA4 diesel cycle. The LA4 cycle (the Los Angeles cycle) is laid down by the Environmental Protection Agency (EPA) in the United States and is a standard test cycle devised to simulate a drive to work in Los Angeles traffic conditions. It is furthermore a test which is used to show the effectiveness or otherwise of an exhaust gas purification unit fitted to an automobile. The hydrocarbons, carbon monoxide, nitrogen oxides and particulates present in the exhaust gas emissions were measured in g $mile^{-1}$. Baseline measurements were taken of the pollutant levels in the exhaust gas before it passed through the catalyst chamber.

The results are given in Table 1 as follows:

Table 1

		Baseline	*Catalyst Chamber A*	*Catalyst Chamber B*
Particulates g $mile^{-1}$ percentage change		0.4	0.31 22.5	0.32 20
NOX g $mile^{-1}$ percentage change		1.75	2 −14.3	2.1 −20
CO g $mile^{-1}$ percentage change		1.25	0.2 84	0.46 63
HC's g $mile^{-1}$ percentage change		0.2	0.07 65	0.11 45
Back Pressure Nm^{-2}	Max percentage difference	13545	22011 −62.5	22688 −67.5
	Min percentage difference	3386	4402 −30	4402 −30

Example 2

A commercially available car with a 2.2 litre turbocharged diesel engine was fitted with a catalyst chamber after the turbocharger as described above with reference to Figure 5. The catalyst was supported on a substrate of knitted wire fabricated from 304 stainless steel wire of diameter 0.254 mm and 0.127 mm before being treated to produce flattened wire. Knitmesh fabricated from the small

diameter wire was used t make up the inner portion of the substrat and the outer portion was made up fr m the knitmesh fabricated from th larger diameter wire. A washcoat of alumina containing barium oxide and ceria was applied to the substrate at a loading of 0.22 g^{-1} wire. The catalytic metal used was $7\frac{1}{2}$ Rh $92\frac{1}{2}$ Pt at a loading of 0.09% by weight. The total catalyst volume was 2.6 litres.

With the car running through the LA4 cycle the baseline measurement of particulates was 0.4 g $mile^{-1}$. After the exhaust had passed through the chamber the level of particulates present was 0.19 g $mile^{-1}$ which is a reduction of 52.5%. The maximum back pressure over the whole system was 13545 Nm^{-2}.

Example 3

A series of tests were conducted using a diesel engine of capacity 14748 cm^3 turbocharged to 1.6 bar. A catalyst chamber was fitted 1.22 m from the turbocharger and contained 9 catalysts arranged in rows as shown in Figure 7. The volume of catalyst used was 21303 cm^{-3}. The substrate, washcoat and catalytic metals used were the same as the catalyst tested in Example 2.

The engine was run through the EPA 1980 new transient cycle test as laid down by the EPA in the USA. Measurements of the level of particulates present in the exhaust gas after the catalyst chamber were taken at intervals of 5 hours. The results are given in Table 2 below.

Table 2

Baseline	*Particulates in g MJ^{-1} After catalyst chamber*	*Percentage change*
0.0224	0.0745	66.7
	0.0782	65
	0.0745	66.7
	0.1043	53.4
	0.0820	63.4
	0.0708	68.4
	0.0782	65
	0.0931	58.4

The level of hydrocarbons in the exhaust gas was reduced from 600 ppm to 12 ppm by the catalyst chamber. The maximum temperature of the exhaust through the chamber was 388°C. The maximum back pressure of the chamber was 249 Nm^{-2}.

The examples show the effectiveness of our catalyst chamber to remove particulates and other pollutants from an exhaust gas emitted from a diesel IC engine even when the chamber is positioned at a distance from the engine and has to operate at a lower temperature.

The catalysts used in the said internal combustion engines comprise:

(a) a divided substrate which is positioned in the path of the gas flow so as to create turbulence in the exhaust gas stream,

(b) an adherent refractory metal oxide washcoat layer disposed upon the surface of the substrate, and

(c) Ru, Rh, Pd, Ir, Pt, Fe, Co, Ni, V, Cr, Mo, W, Y, Ce, alloys thereof and intermetallic compounds containing at least 20% by weight of one or more of the said metals disposed upon the surface or throughout the refractory metal oxide washcoat layer.

The refractory metal oxide washcoat layer contains in the form of their oxides one or more of Mg, Ca, Sr, Ba, Sc, Y, the lanthanides, Ti, Zr, Hf, Th, Ti, V, Cr, Mn, Co, Ni, B, Al, Si and Sn.

A preferred washcoat material is Al_2O_3 and alumina hydrates, a stabilising oxide such as BaO and oxides promoting catalytic activity such as TiO_2, ZrO_2, HfO_2, ThO_2, Cr_2O_3 and NiO may also be present.

One form of catalyst substrate comprises a structure made up from woven or knitted wire and an even more preferred form is woven or knitted wire which has been rolled flat before fabrication into woven or knitted form. Suitable alloys which may be used in the manufacture of the wire are corrosion resistant and particularly oxidation resistant base metal alloys.

Examples of such base metal alloys are a nickel and chromium alloy having an aggregate Ni plus Cr content greater than 20% by weight, and an alloy of iron including at least one of the following: chromium 3—40 wt%, aluminium 1—10 wt%, cobalt trace 5 wt%, nickel trace 72 wt% and carbon trace 0.5 wt%. Such substrates are described in German DOS 2450664.

Other examples of base metal alloys capable of withstanding the rigorous conditions required are iron-aluminium-chromium alloy which may also contain 0.5—12 wt% Al, 0.1—3.- wt% Y, 0—20 wt % Cr and balance Fe. These are described in United States Patent No. 3298826. Another range f Fe-Cr-Al-Y alloys contain 0.5—4 wt% Al, 0.5—3.0 wt% Y, 20.0—95 wt% Cr and balance F and these are described in United States Patent No. 3027252.

Alternatively the base metal alloys may have less corrosion resistance, e.g. mild steel, but with a protective coating composition covering the surface of the substrate as described in our co-pending British Patent Application No. 7903817 dated 2nd February 1979 (which has been published as GE 2012517A).

With wire as the substrate its thickness is preferably 0.0254—0.508 mm and more preferably 0.0254—0.305 mm.

Claims

1. A turbocharged internal combustion engine having a chamber containing a catalyst for removal of pollutants from the exhaust gas from the engine by catalytic oxidation of the pollutants prior to exit of the exhaust gas from the engine.

2. A turbocharged internal combustion engine according to claim 1 wherein a divided substrate is disposed in the path of the exhaust gas flow for inducing turbulence in the gas.

3. A turbocharged internal combustion engine according to claim 1 or 2 wherein the catalyst chamber is located adjacent and contiguous with the outlet ports of the engine cylinders prior to the turbocharger.

4. A turbocharged internal combustion engine according to claim 1 or 2 wherein the catalyst chamber is located adjacent and contiguous with the turbocharger exhaust outlets.

5. A turbocharged internal combustion engine according to claim 1 or 2 wherein the catalyst chamber is located adjacent and contiguous with an exhaust pipe which is connected with the turbocharger exhaust outlet.

6. A turbocharged internal combustion engine according to claim 1 or 2 wherein the catalyst is annular and supported on a perforate exit tube.

7. A turbocharged internal combustion engine according to claim 1 or 2 wherein the catalyst is supported on longitudinal, intersecting members.

8. A turbocharged internal combustion engine according to any preceding claim, in which the catalyst chamber contains dispersed metallic wire having deposited on the surface thereof a first layer comprising a refractory metal oxide washcoat and a second layer comprising a catalytic metal.

9. A turbocharged internal combustion engine according to claim 8 wherein the catalytic metal is one or more of Ru, Rh, Pd, Ir, Pt, Fe, Co, Ni, V, Cr, Mo, W, Y, Ce, alloys thereof and intermetallic compounds containing at least 20% by weight of one or more of the said metals disposed upon the surface or throughout the refractory metal oxide washcoat layer.

10. A turbocharged internal combustion engine according to claim 8 wherein the refractory metal oxide washcoat is in the form of their oxides one or more of Mg, Ca, Sr, Ba, Sc, Y, the lanthanides, Ti, Zr, Hf, Th, Ti, V, Cr, Mn, Co, Ni, B, Al, Si and Sn.

11. A turbocharged internal combustion engine according to claim 8 wherein the washcoat is Al_2O_3 and alumina hydrates.

12. A turbocharged internal combustion engine according to claim 11 wherein the washcoat also contains a stabilising oxide.

13. A turbocharged internal combustion engine according to claim 11 or 12 wherein the washcoat also contains oxides promoting catalytic activity.

14. A turbocharged internal combustion engine according to claim 8 wherein the dispersed metallic wire is knitted, woven or crushed.

15. A turbocharged internal combustion engine according to claim 14 wherein the knitted or woven metallic wire has been rolled flat before being knitted or woven.

16. A turbocharged internal combustion engine according to claim 8 or 14 wherein the wire is corrosion resistant.

17. A turbocharged internal combustion engine according to claim 8 or 14 wherein the wire is an oxidation resistant base metal alloy.

18. A turbocharged internal combustion engine according to claim 17 wherein the base metal alloy is one of a nickel and chromium alloy having an aggregate Ni plus Cr content greater than 20% by weight, and an alloy of iron including at least one of the following: chromium 3—40 wt%, aluminum 1—10 wt%, cobalt trace 5 wt%, nickel trace 72 wt% and carbon trace 0.5 wt%.

19. A turbocharged internal combustion engine according to claim 17 wherein the base metal alloy is an iron-aluminium-chromium alloy.

20. A turbocharged internal combustion engine according to claim 19 wherein the alloy contains 0.5—12 wt% Al, 0.1—3.- wt % Y, 0—20 wt% Cr and balance Fe.

21. A turbocharged internal combustion engine according to claim 19 wherein the alloy contains 0.5—4 wt % Al, 0.5—3.0 wt% Y, 20.0—95 wt% Cr and balance Fe.

22. A turbocharged internal combustion engine according to claim 8 or 14 wherein the substrate has a protective coating over the surface.

23. A turbocharged internal combustion engine according to claim 8 or 14 wherein the thickness of the wire is 0.0254—0.508 mm.

24. A turbocharged internal combustion engine according to claim 8 or 14 wherein the thickness of the wire is 0.0254—0.305 mm.

25. A proc ss for the reduction of pollutants, in exhaust gas from turbocharged internal combustion engines comprising passing the exhaust gas from the cylinders of the engine through a chamber containing a catalyst such that the pollutants present in the exhaust gas come into contact with the catalyst and at least part of the pollutants undergoes catalytic oxidation.

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